Technical Assignment

Background

Perfusion cardiac magnetic resonance (CMR) has been shown to improve the detection of coronary artery disease (CAD). This assignment focuses on the quantification of myocardial blood flow (MBF), which can provide better regionalized assessment of myocardial viability when compared to qualitative assessment. (See attached literature for references)

Provided Resources

- Literature to provide initial context and background, where particularly useful sections/figures of relevance have been noted:
  - Quinaglia_2019: General information on stress perfusion CMR. Note in the section on *Gadolinium enhancement and myocardial blood flow*, that a quantification approach based on the central volume theorem is described, using deconvolution and approximating the transfer function with the Fermi function model.
  - Jerosch-Herold_1998: This paper provides details on using the Fermi function model to quantify myocardial blood flow. The Fermi function defined in this paper is a general form. You may choose to use a more simplified version for this assignment.
  - Wang_2004: A recent study evaluating the quantification of MBF to detect CAD. This paper visualizes the clinical procedures (Figure 1) and displays resulting MBF maps comparing healthy and unhealthy cases (Central Illustration on page 1439).
  - Note that in all of the literature, short-axis cardiac perfusion images are used for quantifying the MBF of the left ventricle (LV).
- A folder "Motion Corrected Perfusion Series":
  - Provides DICOM images of a time-series of a short-axis, motion-corrected perfusion CMR study, at one slice location. Each image represents the same anatomical position scanned at the same cardiac point of the cardiac cycle across multiple heart beats, as contrast agent is flowing through the body.
  - To simplify this assignment, the signal intensities in the blood pool region have been artificially adjusted.
  - You may find useful information in the DICOM metadata when working with the images.
- A file "AIF_And_Myo_Masks.tiff":
  - This file consists of two images containing segmentation masks that correspond to anatomical regions for the sample study.
  - The first image provides a mask corresponding to the blood pool region. Extracting the signal intensities of this mask across the perfusion series will provide the arterial input function (AIF), as shown in Figure 5 of Quinaglia et al. (2019).
  - The second image provides a mask corresponding to the LV myocardium. Extracting the signal intensities of each pixel across the time series for this mask will correspond to the measured tissue curve, as shown in Figure 5 of Quinaglia et al. (2019).

Assignment Objectives:

1) Explore the topic of stress perfusion MR at a high-level, with a focus on the quantification of myocardial blood flow via deconvolution. You may use other resources in addition to the provided literature. Share your understanding of the topics in a ~10 min presentation.
2) Apply the concepts in a coding activity to post-process the sample perfusion images, generating a parametric map (representing MBF) for the myocardial region-of-interest (ROI). This can be achieved by using relevant information from the DICOM images:
   a) Extracting the AIF signal intensity (SI) from the perfusion images using the blood pool mask to acquire a SI-time signal, AIF(t).
   b) Extracting the signal intensities for the myocardial region using the myocardium mask, to acquire SI-time signals, MYO(t), for each pixel in the ROI.
   c) Using the AIF regional SI-time curve and myocardial SI-time curves to quantify MBF for each pixel in the myocardial ROI. There is more than one approach to derive the MBF value for each pixel in the ROI. One set of potential steps:
      i. Perform deconvolution of the extracted 1D discretely-sampled time signals AIF(t) and MYO(t) to find the tissue impulse response function h(t) for each myocardial pixel. This relationship is depicted in Figure 5 and described in the text of Quinaglia et al (2019).
      ii. In the next step, try to find the parameters of a Fermi function F(t) that best describes the h(t) found from the previous step. Note that this Fermi function is defined in Jerosch-Herold, 1998, however, feel free to use alternative versions based on the Fermi function. Use the fitted impulse response function from the previous step F(t) to estimate the myocardial blood flow, where MBF = F(t=0) $[\frac{mL_{blood}}{mL_{myo\ tissue}\ s}]$. Scale the MBF map to units of $\frac{mL_{blood}}{g_{tissue}\ min}$ using a myocardial tissue density of 1.05 g/ml.

Share your thought process, code design, intermediate outputs (plots of AIF, MYO and h(t) along with the fitted Fermi function), and display the MBF map/values. We encourage you to structure your code and solution in a way that facilitates sharing and collaborative development. Please include instructions and documentation on how to build and run your code.

Beyond these guidelines, the level of tooling and refinement is up to you. We are interested in 1) seeing how you approach and solve research & development problems, and 2) how you develop and organize your code during implementation.

Additional notes:

- The use of C++ and/or python is preferred
- Open source libraries can be utilized (e.g., OpenCV, DCMTK, etc.)